(49) **Kármán & Rubach.** Phys. Ztschr., 1912.
**Kármán.** Göttinger Nachrichten, 1911.
(50) **Föppl, L.** Münchener Sitzungsber., 1913, Hft. 1. [A formation of two vortices with a symmetrical body of practically any shape.] *See* **Lanchester.** Aerodynamics, p. 39.
(51) **Lamb.** Hydrodynamics, p. 217.
(52) **Helmholtz.** Berlin Sitzungsb., 1888, p. 647–663; 1889, p. 761–780. *Translated in* **Abbe.** Mechanics of the earth's atmosphere, [II], Washington, 1891, p. 78–111.
(53) **Rayleigh.** Theory of sound, v. **2**, p. 382.
(54) **Exner.** Wiener Berichte, 1911, p. 1411.
(55) **Margules.** On the energy of storms. *Translated in* **Abbe.** Mechanics of the earth's atmosphere, III, Washington, 1910, p. 533–595, and abstracted in this REVIEW, **33:**519.
(56) For instance, see the United States Weather map of the Northern Hemisphere, Washington, D. C., Jan. 8, 1914.
(57) **Kelvin.** Proc. Roy. Irish acad., 1889; Math. and phys. papers, v. **4**, p. 202–204.
(58) **Margules.** Meteorologische Zeitschrift, **Hann Band**, 1907, p. 243.
(59) **Sandström.** Arkiv f. mat., astr., och fys., 1912.
(60) If the velocity of the air above the surface of discontinuity relative to that below, has a component directed upward the intensity of the vortex sheet increases; if, on the other hand, the relative velocity has a component directed downward, the intensity decreases.
(61) **Schmidt.** Wiener Berichte, IIa, 1913, **122:**835–911. For the theory of air waves see the discussion in the Report of the British Association, 1908, p. 605–611; also a paper by **Lamb.** Proc. Roy. soc., 1911, **84A.**
(62) See for instance: **Hadamard.** Propagation des ondes. 1903, chapt. 2.
**Lamb.** Hydrodynamics, p. 464.
I do not think Lord Rayleigh's objection that the equation of energy can not be satisfied, is valid when the tangential velocity as well as the normal velocity is discontinuous.
(63) **Shaw, W. N.** Forecasting weather, p. 246.
(64) **Schmidt, W.** Meteorologische Zeitschrift, 1910, **27:**406. *See also* **Lanchester.** Aerodonetics, 1910, p. 260.
(65) **Okada, Y.** Tohoku Univ'y sci. reports, June, 1914, **3:**189–197.

## III. THE DISTRIBUTION OF THE RAINFALL IN THE WESTERN UNITED STATES.

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[Dated: North Finchley, England, Feb. 24, 1915.]

In this REVIEW for January, 1915, the writer mapped in some detail and discussed the distribution of rainfall intensity in the eastern United States; the present paper is a similar discussion of the rainfall intensity in the western portion of the Republic.

The accompanying 12 monthly maps of equipluves (figs. 31–42) present a notable regularity almost throughout the year, a very wet area gradually fades off into a very dry district. The exceptional month is October, when the raininess is uniformly below the average, and the elevated lands are wetter than the lowlands. The second general feature is the absence of very marked raininess or dryness on the mountains at any time of the year. This fact is well shown by the graphs for the mountain divisions (fig. —). Consequently, in a broad way, the West contains three regions with three types of rainfall: (1) The Far West, including the coast lands, with great rainfall intensity throughout the period November to March, i. e., *winter rains;* (2) the Mountains, never very wet, never very dry; (3) the Eastern Slopes, with great rainfall intensity in the north from April to June, and in the south from July to September, i. e., *summer rains.*

In January the equipluves run north and south and raininess decreases steadily eastwards. This month marks the climax of the influences which cause rain and which are due, in the main, to the winds from the Pacific Ocean.

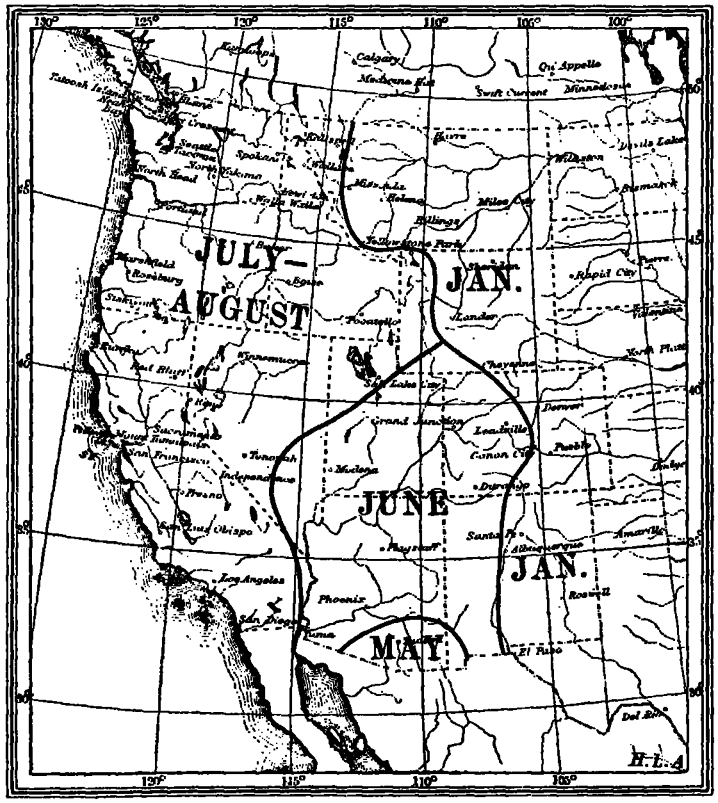


FIG. 24.—Map showing the driest months in the western United States.

In February the rainfall influences begin to weaken along the northwest coast and raininess increases on the eastern slopes.

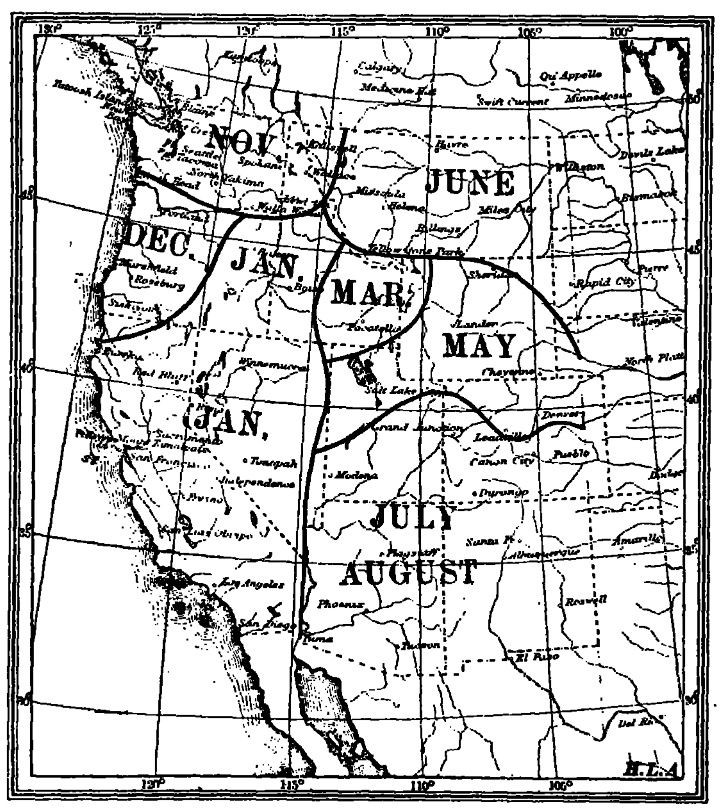


FIG. 25.—Map showing the wettest months in the western United States.

In March the northeast increases in wetness and the western influences weaken generally. By the month of April the influence of the Pacific winds has ceased to produce a marked intensity of rain and continental influences—due, in the main, to the "swing of the sun"—tend to produce raininess in the areas most remote from the sea; the area of great rainfall intensity is latitude 40°–45° N. on the eastern slopes.

In May the continental influences exert a maximum effect in this central area, and the southwest corner is relatively very dry. The June areas of wetness and dryness lie to the north of those which occur in May.

In July the extreme southern section of the Mexican boundary of the United States, which lies within 3 or 4 degrees of the Tropic of Capricorn, begins to experience the northward-moving area of heavy rainfall always accompanying the "vertical" sun. Dryness prevails


FIG. 26.—Rainfall regions of the western United States.

over the western coast lands. In August, July conditions are continued and develop a more definite dryness in the north. In July and August the Pacific coast lands are marked by an exceptional dryness (below 10 per cent), being the minimum intensity of rainfall occurring anywhere in the United States.

In September the southern maximum and the western minimum persist, but in a less marked degree. October is a dry month in the United States, and it is slightly drier in the West than farther east. In November and December the oceanic influences begin to work toward their January maximum; they increase in power as the winter comes on and as they gradually reach farther southward.

Figures 24, 25, and 26 are based upon the monthly maps (figs. 31–42).

Roughly a line from El Paso to Missoula divides the United States into two parts having dry winters and dry summers, respectively.

On the other hand, meridian 115° W. divides the country into two parts which have wet winters and wet summers, respectively (fig. 25). Both these statements ignore the small coastal area of New England where the rainfall conditions tend to be unique.[1] Consequently, the western United States may be divided (fig. 26) into three rainfall areas: (*A*) the west coast with wet winters

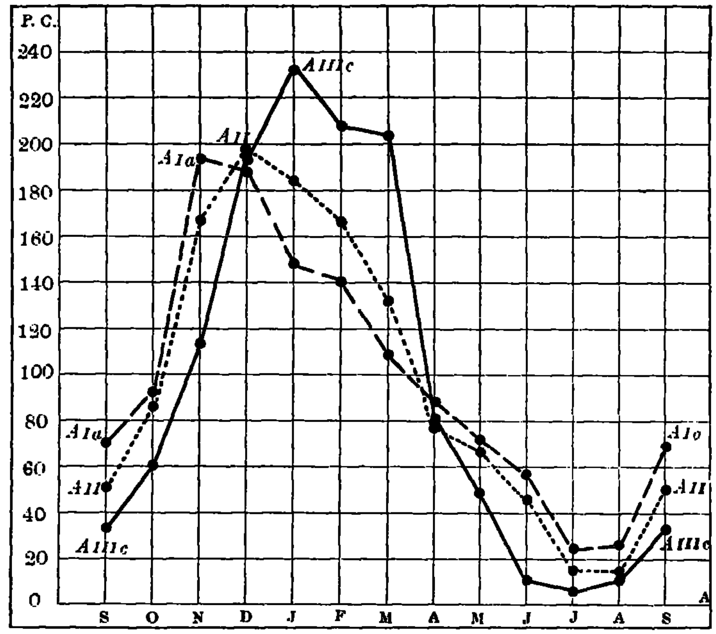


FIG. 27.—Annual march of rainfall intensity in rainfall regions *A Ia*, *A II*, and *A IIIc*. (See fig. 26.)

and dry summers and a great range of rainfall intensity; (*B*) the eastern slopes with seasons the reverse of these, and also a great range of intensity; and (*C*) the mountains with indefinite rainfall seasons accompanied by a slight range of intensity, although the cold season tends to be rainier than the warmer half year.

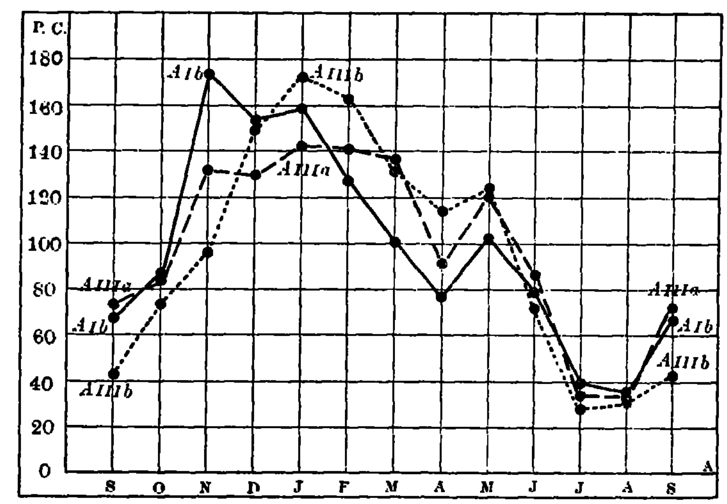


FIG. 28.—Annual march of rainfall intensity in rainfall regions *A Ib*, *A IIIa*, and *A IIIb*. (See fig. 26.)

In the west coast divisions (fig. 27) the oceanic influences found on the north gradually increase in intensity southward. On the other hand, the oceanic influences decrease in intensity with distance from the coast (fig.

[1] See this REVIEW, January, 1915, 43: 16, 17, figs. 8 and 10.

28). The three areas, for which generalized graphs are shown, agree in having increased raininess which prevails in May in comparison with April. This latter fact is of interest in connection with the raininess of the interior of the continent in that month.

Figure 30 refers to the eastern slopes and shows how the maximum effect occurs in the center in May, in the north in June, and in the south in July. The period of heavy rains is also shown to be limited in each portion of the area to approximately three months.

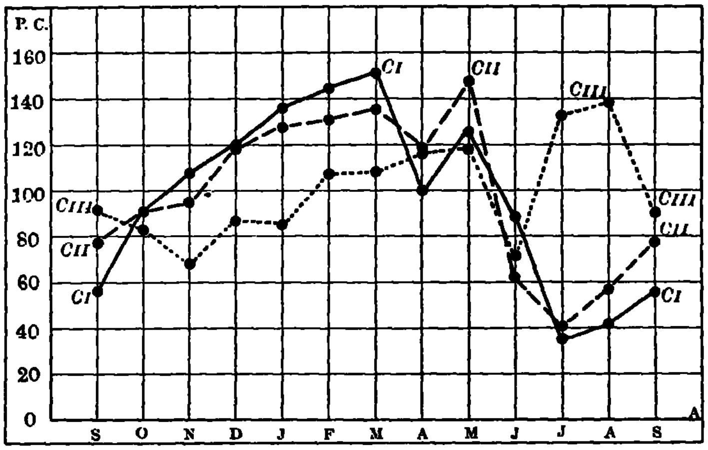


FIG. 29.—Annual march of rainfall intensity in rainfall regions *CI—CIII*. (See fig. 26.)

Figure 29 indicates the details for the mountain division intermediate in location and in type of rainfall between the other two areas. In each case there is a double maximum. It is interesting to note that in general the equinoxes are dates when the rainfall intensity tends to approach its average and when the periods of wetness and dryness, respectively, tend to terminate.

The location of these several rainfall regions are indicated in figure 26. In conjunction with the corresponding chart [2] of the rainfall regions of the eastern United States (fig. 8) figure 26 indicates that the rainfall of the United States as a whole is determined by (1) continental influences which are exerted over a broad triangle of country, with the vertex to the south and with the edge of the Rocky Mountains as the easte n limb of the triangle; (2) oceanic influences exerted upon the coastal

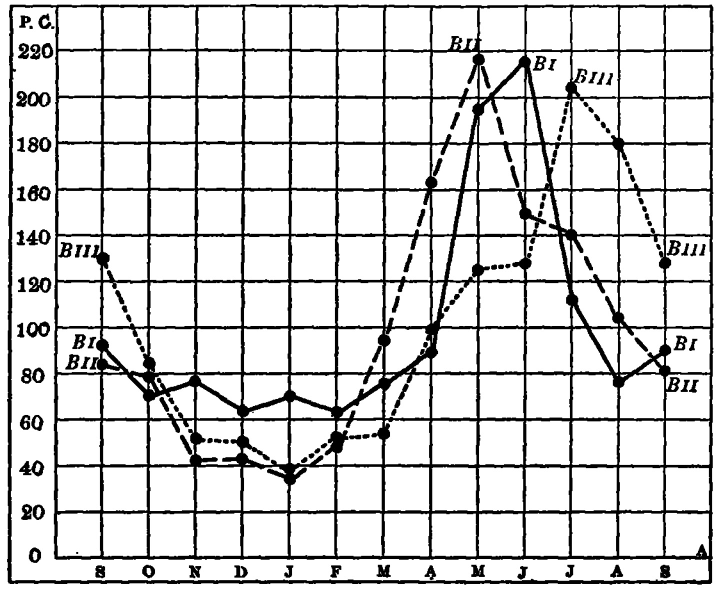


FIG. 30.—Annual march of rainfall intensity in rainfall regions *BI—BIII*. (See fig. 26.)

lowlands, (*a*) on the west from the Pacific and (*b*) on the east from the Atlantic; (3) intermediate regions (*a*) the Rockies in the west and (*b*) the western Appalachians on the east; and (4) direct solar influences which are manifest with some elements of variety along the southern boundary as far west as Yuma, Ariz.

[2] *See* this REVIEW, January, 1915, 43: 16, 17, figs. 8 and 10.

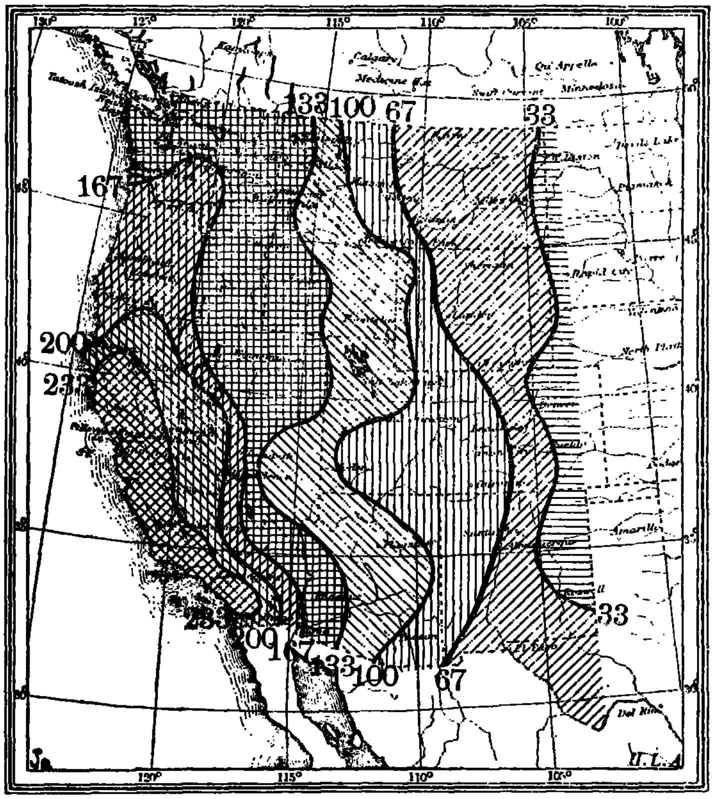

FIG. 31.—Equipluves for the western United States for January.

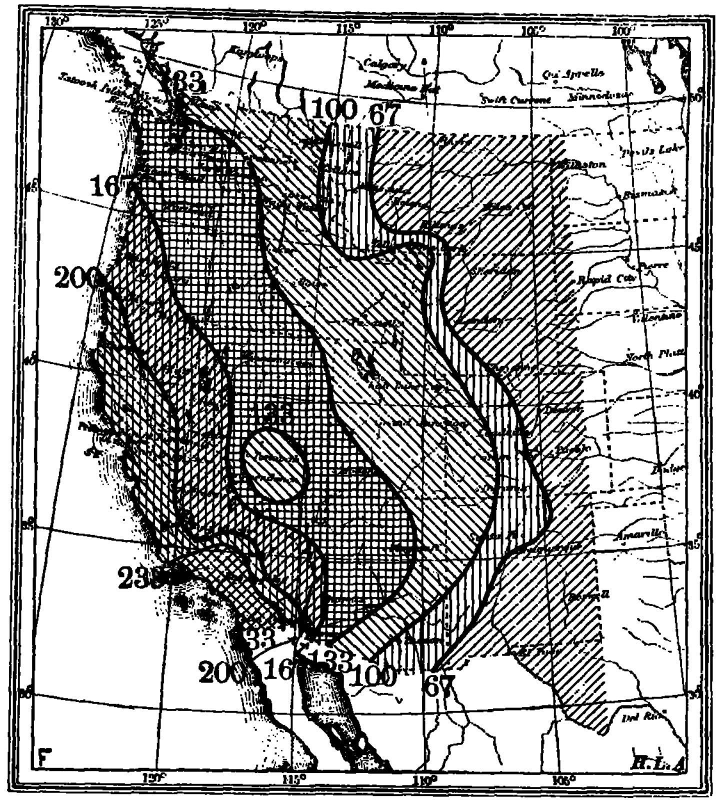

FIG. 32.—Equipluves for the western United States for February.

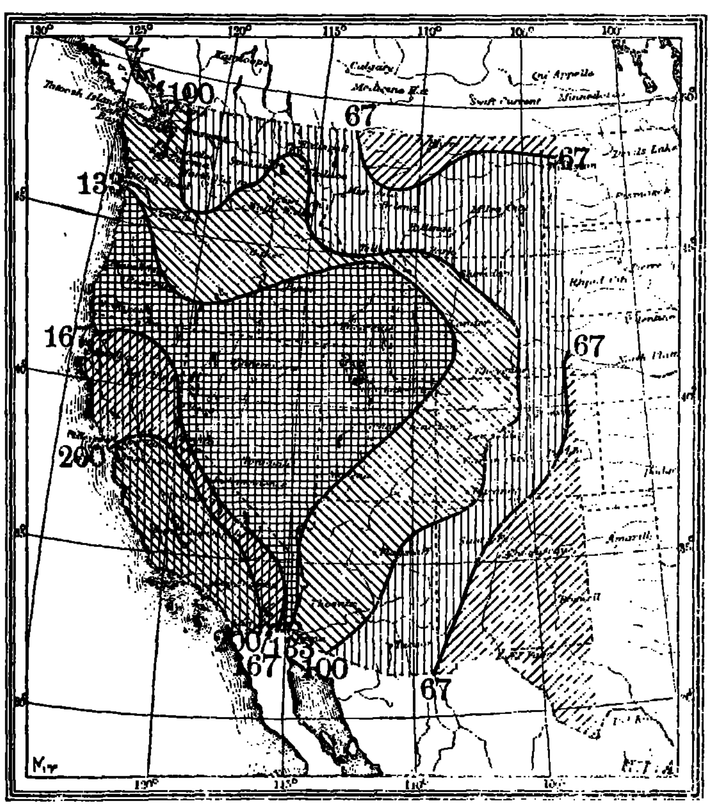

FIG. 33.—Equipluves for the western United States for March.

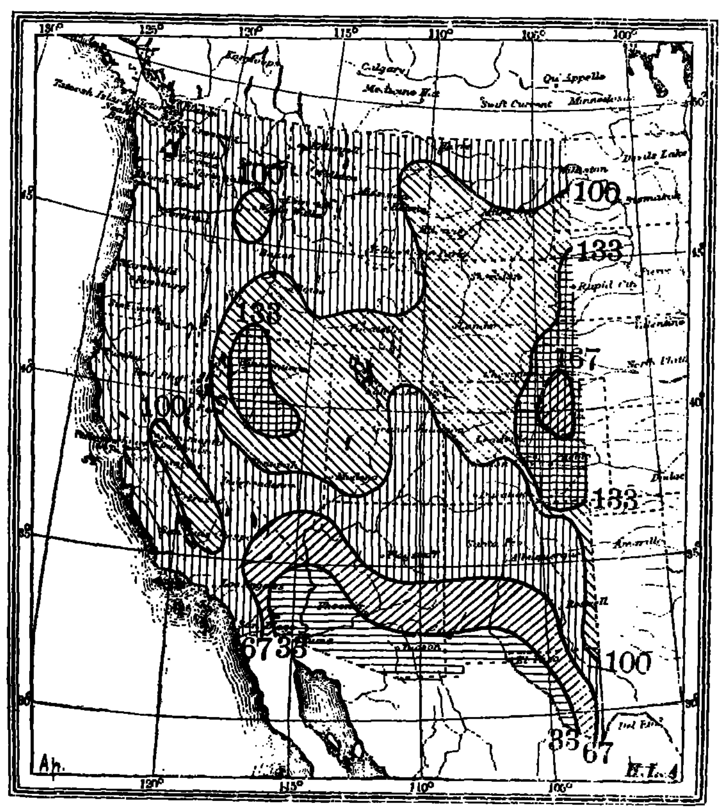

FIG. 34.—Equipluves for the western United States for April.

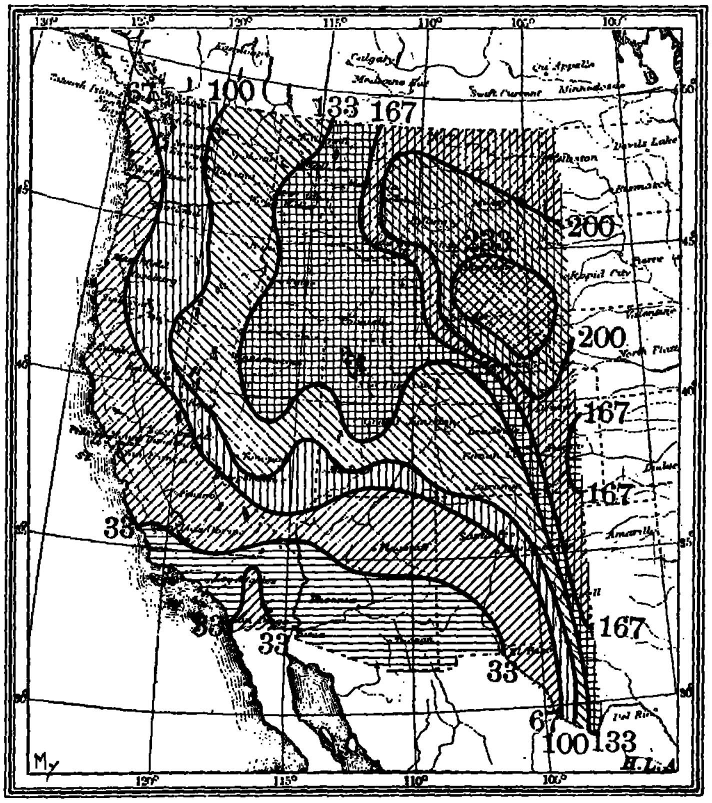


FIG. 35.—Equipluves for the western United States for May.

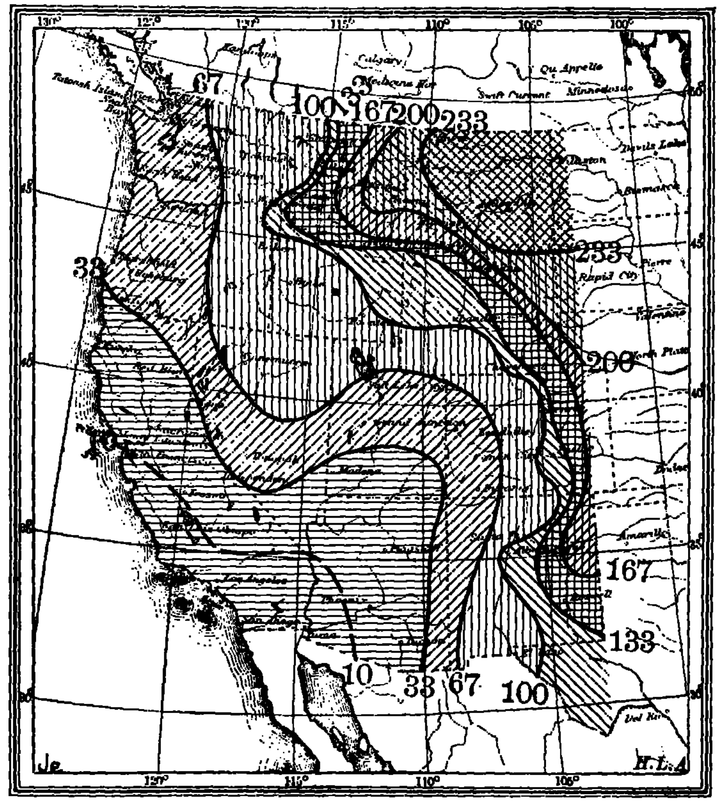


FIG. 36.—Equipluves for the western United States for June.

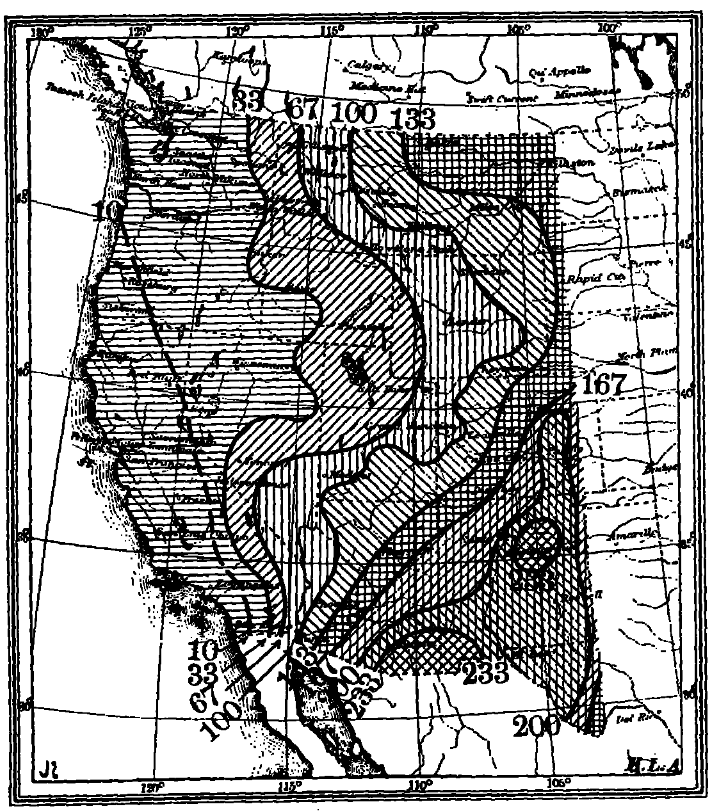


FIG. 37.—Equipluves for the western United States for July.

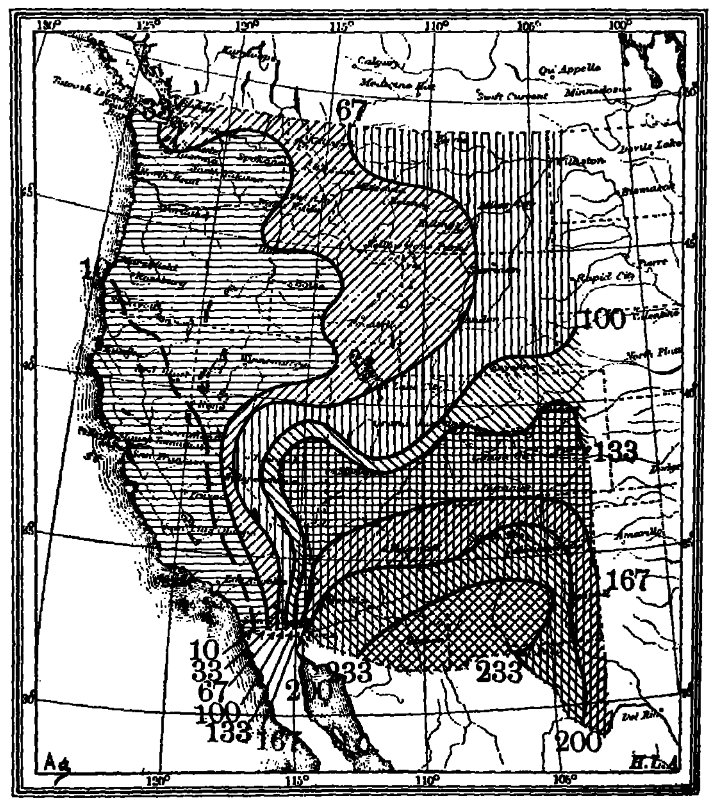


FIG. 38.—Equipluves for the western United States for August.

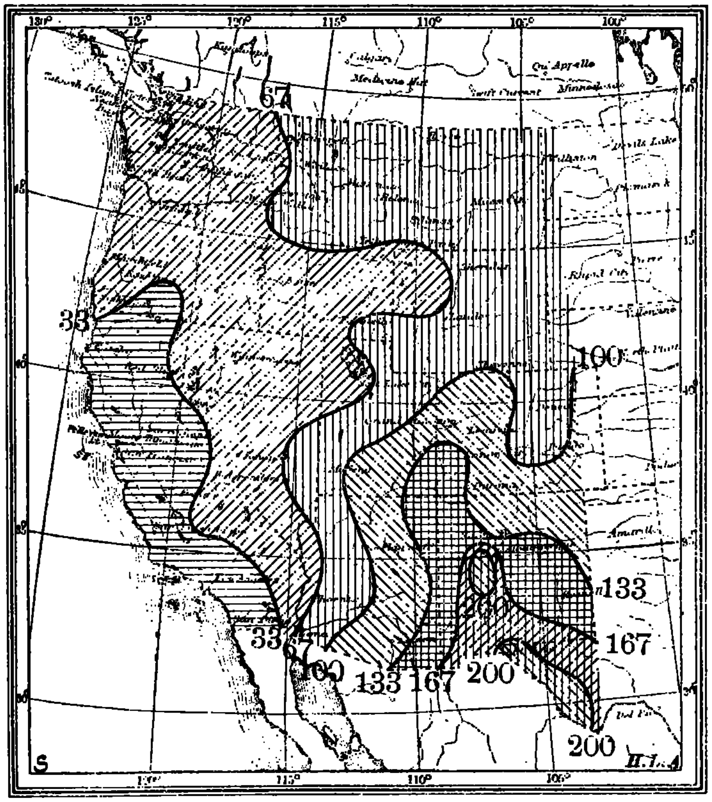

FIG. 39.—Equipluves for the western United States for September.

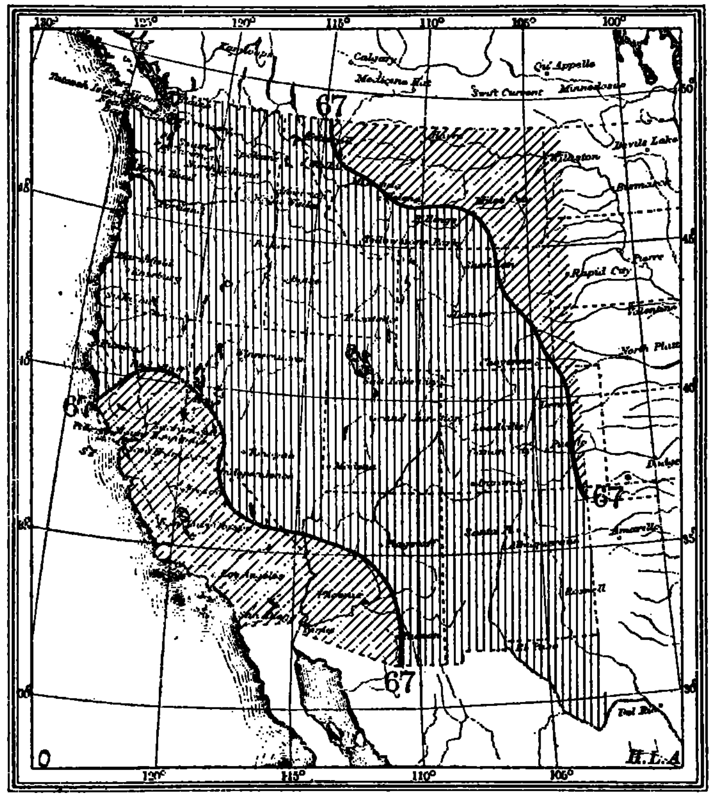

FIG. 40.—Equipluves for the western United States for October.

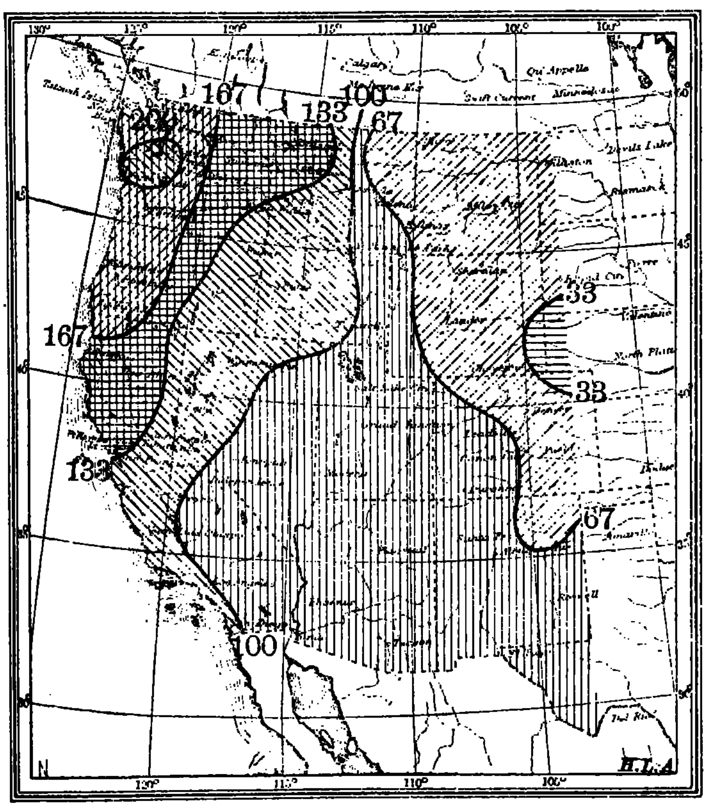

FIG. 41.—Equipluves for the western United States for November.

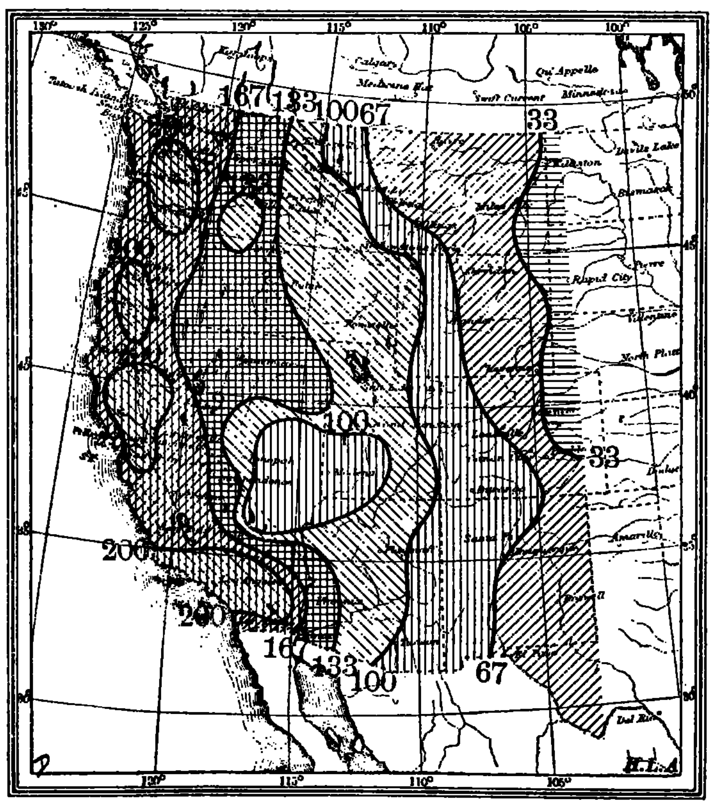

FIG. 42.—Equipluves for the western United States for December.

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